	Shinano	Clyde	
		I	II
SiO_2	0.64	0.12	......
Fe_2O_3	3.44	5.36	......
Al_2O_3	1.00	0.12	......
CaO	52.33	46.60	47.63
MgO	0.48	4.94	4.21
CO_2	37.00	36.40	39.91
P_2O_5	......	......	2.23
Organic matter	......	......	5.94
	94.89	93.54	100.22[3]

An exceedingly comprehensive work on the mineral springs of Japan has just been published by Dr. R. Ishizu, expert of the Imperial Hygienic Laboratory at Tokyo.[4] No less than 1,201 of these springs are tabulated, and a very large number of analyses are given, as well as tables of the radioactive springs of Japan, and of the leading European springs of this interesting class. Part III. offers notes on prominent spas and resorts. The numerous plates illustrate the scenic beauties of the various localities.

GEORGE F. KUNZ

SPECIAL ARTICLES

ANTAGONISTIC ELECTROLYTE EFFECTS IN PHYSICAL AND BIOLOGICAL SYSTEMS[1]

THE purpose of this paper is to summarize briefly certain experiments regarding the influence exerted by antagonistic electrolytes on emulsions and other physical systems, and to compare the data in question with those avail-

[3] The summation is .30 in error, which exists in the manuscript.

[4] "The Mineral Springs of Japan," with tables of analyses, radioactivity, notes on prominent spas and list of seaside resorts and summer retreats, specially edited for the Panama-Pacific International exposition, by Dr. R. Ishizu, expert of the Imperial Hygienic Laboratory, Tokyo Imperial Hygienic Laboratory, 1915, x + 94 + 203 + 70 + 8 pp., maps and illust., and 76 plates, folio.

[1] A summary of a paper read before the Biological-Chemical Society, Boston, Mass., December 28, 1915. Received for publication December 29, 1916. Publication delayed on account of necessity of condensation within suitable dimensions for this journal. (From the Biological-Chemical Laboratory of the State Institute for the Study of Malignant Disease, Buffalo, N. Y.)

able regarding the influence exerted by the same antagonistic electrolytes on living cells, in an attempt to throw some light on the physical structure of protoplasm and the mechanism of certain vital processes.

In spite of the accumulation by Jacques Loeb, and other biologists, of a large amount of accurate experimental data regarding the effects exerted by electrolytes, singly and in combination, on living cells, there is, at present, no generally accepted physical explanation for the antagonistic or compensatory effects exerted by electrolytes on one another in biological systems.

In a preliminary communication published in 1913 based on certain physical and biological experiments, details regarding which will be found in a subsequent section of this paper, it was concluded that, with certain exceptions to be considered later, electrolytes may be divided, as regards their effect on the protoplasmic membrane, into two main antagonistic groups according to whether, like $CaCl_2$, they possess a more readily adsorbed or reactive cation, or, like NaOH, NaCl, etc., a more readily adsorbed or reactive anion. Substances of the former class appear to diminish the permeability of the membrane to water, while those of the latter class increase the permeability of the membrane. As will be seen later, the ratios in which antagonistic electrolytes counterbalance one another in biological systems correspond so closely with the ratios in which they balance one another in physical systems as to suggest the probability that balanced electrolyte solutions, like sea-water and the blood of mammals, are those in which the proportions of cations and anions adsorbed on or reacting with the protoplasmic membrane are equal, or at least compensatory, with the result that the colloidal equilibrium, and consequently the permeability of the membrane, remains unchanged. A somewhat similar conclusion was reached by Osterhout as a result of experiments on the electric conductivity of laminaria tissues. Under comparable experimental conditions the tissues which had been exposed to sea-water exhibited a practically constant resistance to the passage of an electric current, but, after exposure to solutions of

NaCl, a markedly decreased resistance, and after exposure to solutions of $CaCl_2$, a markedly increased resistance, at least for a short period; but there was no appreciable variation from the normal after exposure of the tissues to mixtures containing NaCl and $CaCl_2$ in the ratios of 100 molecules of the former to one or two of the latter. Osterhout concluded as a result of these and other experiments that electrolytes may be divided into two main antagonistic groups according to whether they raise or lower the permeability of the protoplasmic membrane.

The ratio of 100 molecules of NaCl to 1 or 2 molecules of $CaCl_2$ is one of peculiar significance in biology. NaCl and $CaCl_2$ occur in approximately this ratio in sea-water, the blood of mammals, and other saline media capable of supporting life. Furthermore, marine organisms are killed by transference to artificially prepared solutions of NaCl or $CaCl_2$ isosmotic with sea-water, but they remain uninjured if transferred to a solution of NaCl to which enough $CaCl_2$ has been added to give the ratios in question.

The writer's experiments on emulsions start from an observation made by Bancroft that soaps of Na, used as emulsifying agents for oil and water, give an emulsion consisting of drops of oil dispersed in water like cream, while soaps of Ca exert the reverse effect, producing emulsions consisting of drops of water dispersed in oil like butter. The writer believed that these experiments might offer a physical explanation for the antagonistic effects exerted by salts of Na and Ca on one another, not only in biological systems of the type described above, but also in such purely physical processes as blood coagulation and the production of a casein clot. In the coagulation processes in question the transformation of a suspension of a protein dispersed in water, into a clot in which water is more or less dispersed in an outer or continuous protein phase is promoted by salts of Ca and inhibited or retarded by alkalies and salts of Na. Therefore the first question to determine was whether a similar transformation could be effected in the case of emulsions. In the pre-

liminary paper referred to above the writer was able to demonstrate that suitably constituted emulsions of oil dispersed in water could be converted into emulsions of water dispersed in oil by shaking with salts of Ca, and that the transformation in question could be prevented, or a reverse transformation effected, by shaking with an adequate proportion of NaOH. It was subsequently demonstrated that NaCl, and other salts of Na, exert an effect on emulsion systems similar to that of NaOH but considerably weaker. The processes of blood coagulation and emulsion transformation appear to be similar physical effects promoted by salts of Ca and inhibited by alkalies and salts of Na. In both cases, a system consisting of a non-aqueous phase dispersed in water is converted, more or less perfectly, into a system consisting of water dispersed in the non-aqueous phase, analogous to the transformation of islands surrounded by water into lakes surrounded by land. It is obvious that a system of islands surrounded by water is freely permeable to water and water-borne substances, while a system of lakes surrounded by land is absolutely impermeable. A variety of intermediate systems exhibiting any desired degree of permeability can well be conceived. Since salts of Ca promote a transformation in one direction and alkalies and salts of Na in the reverse direction, it appears probable that by simply varying the proportions of the salts in question introduced into a given system it should be possible to vary the permeability of the system to water to any desired extent. Since variations in the permeability of protoplasm induced by variations in the proportions of salts of Ca and Na appear from Osterhout's experiments to account for the destructive effects exerted by salts of Ca and Na when used individually, and the protective effect exhibited when these substances are used jointly in ratios of 100 molecules of NaCl to 1 or 2 of $CaCl_2$, the question arises how far can such a mechanism as that described above in the case of emulsions and blood coagulation explain protoplasmic structure and function?

From what we know of protoplasm and the protoplasmic film it is by no means incon-

ceivable that the former approximates to a dis-persion of proteins, fats, lipoids, and other colloids in water, while the latter approximates to the reverse type of system in which water is more or less dispersed in an outer or continu-ous phase of fats, lipoids, and possibly proteins. Arguments in support of the view that proto-plasm when first formed is a system rela-tively freely permeable to water because water is the outer or continuous phase are, first, the active Brownian movement exhibited by protoplasm when inspected by means of the ultra microscope; and, second, the freedom with which water-soluble substances, artifi-cially introduced through the protoplasmic film, permeate the protoplasmic material. Arguments in support of the view that the protoplasmic film is relatively impermeable to water, because water is more or less dispersed in an external or continuous phase, consisting at least in part of fats and lipoids, are, first, the resistance offered by the protoplasmic film to the passage of salts, sugars, and other water-soluble substances; second, the resistance to the passage of an electric current; third, the phenomenon of osmotic pressure; fourth, the variations in the proportions of given elec-trolytes within and without the cell; and, fifth, the freedom with which anesthetics and other fat solvents penetrate the protoplasmic system. Since the variations in permeability of proto-plasm under the influence of salts of Ca and Na may well be attributable to a reversal of phase relations analogous to that observed in the case of emulsions, sols and jellies, the next question to determine is whether given elec-trolytes exert antagonistic effects on physical systems in the same ratios as on living cells. Before describing the experiments, it is neces-sary to refer briefly to the explanation offered by Bancroft for the apparently antagonistic action of soaps of Na and Ca in emulsion sys-tems. Pure oil and water when shaken to-gether do not give a permanent emulsion. Soap or some other so-called emulsifying agent must be employed. The emulsifying agent exerts its effect by concentration at the inter-face between oil and water, forming a film which prevents the subsequent coalescence of

the dispersed particles. Bancroft concluded that soaps of Na, which are freely dispersed in water but not in oil, form a film which is wetted more readily by water than by oil, with consequently a lower surface tension on the water than on the oil side, and, since the area of the inside face of a film surrounding a sphere is smaller than that of the outside face, the film will tend to curve in such a manner as to enclose globules of oil in water, thus re-ducing the area of the side of higher surface tension to a minimum as compared with that of lower surface tension. Conversely, a film composed of Ca soap, which is freely dispersed in oil but not in water, is wetted more readily by the oil than by the water, the surface ten-sion is lower on the oil than on the water side, and the film tends to curve in such a manner as to enclose the globules of water in an outer or continuous oil phase.

While studying reversible emulsion systems, the writer observed that when those electro-lytes, like $CaCl_2$, that promote the formation of an emulsion of water in oil are present in such proportion as to balance those, like NaOH or NaCl, that promote the formation of an emulsion of oil in water, a critical point is recognizable at which neither type of emulsion predominates, and the oil and water separate rapidly under the influence of gravity into two layers. This observation affords a strong support of Bancroft's conclusion. Since the electrolytes in question are exerting an exactly compensatory effect on the film it has no tend-ency to curve in either direction, and, since it remains straight, neither phase is capable of surrounding the other. The mixture shaken together really contains two continuous phases analogous to the fiber and air in a sponge, and, since oil and water are both fluids, they sepa-rate readily under the influence of gravity.

Salts of divalent and trivalent cations, and, under certain circumstances, small amounts of acids appear to function in the same way as salts of Ca, promoting the formation of emul-sions of water in oil. Alkalies, salts of mono-valent cations, and of di- and trivalent anions, appear to function similarly to NaOH, pro-moting the formation of emulsions of oil in

water. Studies carried out by means of emulsions of oil and water are altogether too crude to determine the exact ratios in which antagonistic electrolytes exert compensatory effects. After experimenting with various procedures the following method was finally adopted. Aqueous solutions containing NaOH or Na oleate were allowed to run from a Traube stalagmometer or capillary pipette through olive oil containing a certain amount of fatty acid. If solutions of suitable strength were employed, surface films of soap were produced at the interface between oil and water, when the aqueous solution flowed out of the orifice of the pipette and came in contact with the surrounding oil. The size of an individual drop formed, and, since the volume is constant, its inverse the number of drops, depended upon the concentration of the NaOH employed. A $M/1,000$ NaOH solution gave from 40 to 45 drops, while one of half this strength gave from 20 to 25 drops, and one of double the strength gave several hundred drops or ran through the oil in a stream without the formation of any drops whatever. If NaCl was added to a given system of this type, the number of drops was rapidly increased, as will be seen from the accompanying table. If CaCl₂ was added to such a system the number of drops was diminished, but when NaCl and CaCl₂ were employed together they appeared to exert a compensatory effect upon one another in the proportions of 100 molecules of NaCl to one or two molecules of CaCl₂, according to the concentration of the solution employed. (See table.)

TABLE

Exper. No.	Concentration of			No. of Drops	Mol. Ratio NaCl : CaCl₂
	NaOH	NaCl	CaCl₂		
1	.001M	—	—	44	
2	.001M	.15M	—	300	
3	.001M	—	.0015M	24	
4	.001M	.15M	.0015M	44	100 : 1
5	.001M	.3M	.003M	43	100 : 1
6	.001M	.45M	.005M	43	100 : 1.1
7	.001M	.6M	.01M	43	100 : 1.6

To avoid any possibility of confusion, or any idea that this antagonism between CaCl₂ and NaCl is due to an antagonism between Ca

and Na, the writer wishes to emphasize particularly the fact that these antagonistic effects are always attributable to a balance between cations, on the one hand, and anions, on the other, adsorbed on or reacting with a surface film or membrane. It simply happens that, in the case of CaCl₂, the cation Ca is far more readily adsorbed than the anion Cl, while, in the case of NaCl, the anion Cl is somewhat more readily adsorbed than the cation Na. The effect obtained from each individual salt is a resultant of the relative adsorption of cation and anion; and the effect obtained from an admixture of two or more salts is the resultant of the relative adsorption effects exerted by all the cations and anions involved. It will be seen therefore that, while CaCl₂ exerts an effect like an acid on account of its dominant cation, NaCl exerts an effect like an alkali on account of its dominant anion.

The remarkable correspondence between the ratios in which NaCl and CaCl₂ balance one another in these purely physical systems and in the biological systems referred to above led the writer to investigate further the relations exhibited by a variety of electrolytes known to exert antagonistic effects in biological systems. In several hundred experiments, full details regarding which will shortly be published, the writer has been able to duplicate the results obtained by Loeb, Osterhout, Lillie and numerous other biologists, on living cells. The ratios and proportions in which substances having a dominant cation antagonize substances having a dominant anion are approximately the same in the great majority of comparable physical and biological experiments. For convenience in describing experiments those substances having a dominant cation, which diminish the dispersion of the film in water, thus rendering the system less permeable to water, are termed " protective," those having a dominant anion, which increase the dispersion of the film in water, thus rendering the system more permeable to water, are termed " destructive." Even those substances like salts of Mg, and certain non-electrolytes, the anesthetics, which exhibit abnormalities in biological systems, functioning under varying

conditions and varying concentrations as protective or destructive agents, exhibit similar abnormalities when tested by means of the drop system described above. $MgCl_2$, for example, when employed in a drop system in conjunction with Na oleate, lowers the number of drops, exerting an antagonistic effect against NaCl virtually the same as that exerted by $CaCl_2$. When employed in a NaOH system, the $MgCl_2$ acts like NaCl, causing however a far greater rise in the number of drops than NaCl. This effect may be counteracted by means of $CaCl_2$ in proportions varying according to circumstances from one of $CaCl_2$ to one to four of $MgCl_2$. Anesthetics generally exert an effect like salts of Ca, and counteract the destructive effect exerted by NaCl on the film, but, under certain peculiar conditions and at considerably higher concentrations, they may exhibit a destructive effect on the film, causing an increase rather than a decrease in the number of drops. This result is of interest in view of the observation made by Lillie that anesthetics exert protective effects on *Arenicola* larvæ at certain concentrations, and destructive effects at other concentrations; particularly since the proportions in which given anesthetics exert an optimum protective effect on the drop film in our experiments, as indicated by the minimum number of drops, appear to correspond fairly closely with those observed by Lillie. These somewhat remarkable effects are being studied further in the hope of securing an insight into the exact nature of the mechanism involved. These experiments indicate that anesthesia is due to a diminution in the permeability of protoplasm. If the relative effects exerted by monovalent, divalent and trivalent cations are compared, it is found that Ca exerts from twenty to thirty times as great a protective effect on the film as Na, and Fe from 100 to several hundred times as great a protective effect as Na. Mono-, di-, and trivalent anions exhibit similar but less readily recognized ratios. Acids and alkalies exhibit the same peculiarities in these systems as in biological and colloidal systems, the H and OH ions being apparently much more active than other monovalent ions, and, in certain cases,

exhibiting a greater activity than di- or trivalent ions. Weak acids and weak bases exert far less effect than strong acids and strong bases, and the ratios correspond fairly well with the probable concentration of the H or OH ion. The fact that NH_4OH exerts vastly less effect that NaOH, while in biological systems NH_4OH penetrates the protoplasm far more readily than NaOH, is readily explained when we remember that the penetration of NaOH depends upon a destructive effect exerted upon the protoplasmic structure resulting in an actual increase in the permeability of the system to water-borne substances, while NH_4OH presumably penetrates the protoplasmic system on account of its being dispersed or dissolved to a certain extent in the non-aqueous phase.

A single experiment has been selected from a comparative series carried out on animals, on the blood coagulation process, and on the drop system, in order to show that antagonistic electrolytes exert comparable effects in physical and biological systems. $CaCl_2$ and Na citrate were selected for this purpose, not because similar results could not have been obtained by the employment of $CaCl_2$ and NaCl, but because the high concentrations of NaCl required would have exerted a disturbing effect. By mixing a M/10 $CaCl_2$ solution with a chemically equivalent citrate solution in varying proportions, it was ascertained that they exert a compensatory or balancing effect upon one another in the various systems described, when present in the proportions of approximately one equivalent of $CaCl_2$ to two equivalents of Na citrate. $CaCl_2$ in excess of this proportion gave a number of drops less than that given by the original system, Na citrate in excess of this proportion gave a larger number of drops, but when $CaCl_2$ and the equivalent citrate solution were employed in ratios of 1:2, the number of drops obtained corresponded closely with that given by the original system. When the same solutions were injected into the tail veins of mice, it was found that the fatal dose of either the $CaCl_2$ or citrate solution alone was from .25 to .3 c.c. The amount required to cause the death

of the mice rapidly increased when citrate was admixed with $CaCl_2$, or when $CaCl_2$ was admixed with citrate, until finally, when the solutions were employed in the ratios of one equivalent of $CaCl_2$ to two of Na citrate, a destructive effect on the mice could only be observed when, by greatly increasing the concentration, the dose employed was raised to 40 or 50 times that used at either end of the scale. In the process of blood coagulation, all the plasma tubes employed were coagulated rapidly when $CaCl_2$ was present in excess of the ratio of $1:2$, while no coagulation took place in those tubes in which the proportion of $CaCl_2$ was below this figure. From the remarkable similarity exhibited in these three systems, one purely physical, one purely biological, and one semi-physical and semi-biological, it may well be concluded that the equilibrium of both physical and biological systems of the type described depends upon the maintenance of the colloidal equilibrium of surface films, and that balanced solutions are those in which the proportions of cations or anions adsorbed on or reacting with the colloidal constituents of the film are compensatory, and consequently no change occurs in the equilibrium of the system.

These drop systems are peculiarly sensitive to changes in physical conditions and to slight variations, such, for example, as an increase or decrease in the proportion of fatty acid present in the olive oil employed. These variations are of peculiar interest as offering a possible explanation for the variations in permeability to food stuffs of actively growing cells, conditioned not only by variations in the proportions of electrolytes and of metabolic products in their environment, but also by slight variations in the proportions, for example, of lipase or any agent capable of splitting fats or lipoids. In fact these systems are as delicate, or even more delicate than living cells, and are equally difficult to work with. Accurate comparative data can only be obtained by the most scrupulous observance of every possible precaution to insure comparable working conditions, and by taking the average of a very large number of experiments. It is interest-

ing to note in this regard that in such a series of experiments the great majority will lie within a close range of the average, while in certain individual experiments, as in the case of certain individual organisms, extraordinary abnormalities may be exhibited. It is not possible in this brief preliminary communication to explain fully the mechanism of the drop system, but it may be stated briefly that those forces which promote an increase in the number of drops are always comparable with those which promote the formation of emulsions of oil in water or a system more permeable to water, while those which exert the reverse effect causing a diminution in the number of drops are those which promote the formation of emulsions of water in oil or a system relatively less permeable to water. This is due presumably to the influence exerted by various reacting or adsorbed anions or cations on the relative dispersion of the constituents of the film in water, on the one hand, and oil, on the other, thus changing the relative surface tension on the two sides of the film, and promoting the formation according to circumstances of a system in which the permeability to water and water-borne substances is increased or diminished.

To turn now to the question as to how this bears on the problem of protoplasmic structure: it is probable that not only soap films, but all concentration films formed at the interface between two non-miscible phases, tend to be more or less similarly influenced by adsorbed substances. It is not proposed at this stage to consider the case in which the effects produced are simply due to an electric charge conveyed by adsorbed cations or anions, a subject which will be dealt with in a subsequent communication, but simply those cases in which definite soap films are formed and play a rôle in conditioning the equilibrium of the system. We know that fats and lipoids play an important rôle in the protoplasmic film. We know that soaps are present in the protoplasmic system, and, since the soaps in question will tend to concentrate, as has been seen above, at the interface between the particles of fatty or lipoid material and water, it is quite

conceivable that, when naked protoplasm comes in contact with an environing medium, like sea-water, capable of supporting life, the dispersed particles of fatty or lipoid material which find themselves immediately on the surface in contact with the sea-water are immediately influenced by the Ca in the sea-water. The system which consists of fatty or lipoid material, dispersed by means of a soap film in water, might be converted more or less perfectly into the reverse type of system, in which water is dispersed by means of a soap film in an external fatty or lipoid phase. The permeability of such a system to water, the extent to which water channels would be formed from point to point through such a film or membrane, might well depend on the proportions of those electrolytes like $CaCl_2$, on the one hand, which tend to render the system less permeable, and those like $NaCl$, on the other, which exert the reverse effect. Taking as an example the conversion of a dispersion of particles of wax in water into a honeycomb-like structure in which the water phase is surrounded by the continuous wax walls of the cells, it can readily be appreciated that any agent capable of corroding or perforating the walls of the honeycomb structure would promote the continuity of the previously dispersed water phase, and ultimately open up water channels of communication throughout the whole system. Agents capable of exerting the reverse effect, tending to protect the wax walls, would obviously antagonize the agents corroding or breaking down the walls, with the result that the permeability of such a system would depend ultimately upon the proportions in which the antagonistic agents in question are present in the system. The writer believes that a somewhat similar explanation might be found for the formation of the protoplasmic film, and that the antagonism between electrolytes possessing a more readily adsorbed cation, which tend to promote the formation of a less permeable system, and those possessing a more readily adsorbed anion, which tend to exert the reverse effect, may be accounted for on the lines indicated.

Proteins present in protoplasm being trans-formed under the influence of Ca into a non-reversible system analogous to a blood clot might well form a sort of framework and confer a certain rigidity, elasticity, and continuity to the membrane structure. Fatty or lipoid materials which produce readily reversible emulsion systems in conjunction with water, when supported by a protein framework, might yield a system sufficiently sensitive to exhibit variations in permeability to water under the influence of varying proportions of such antagonistic electrolytes as $NaCl$ and $CaCl_2$.

CO_2, and other products of metabolism, exert a profound effect upon the equilibrium and relative surface tension relations of interfacial soap films, and it is hoped in a subsequent publication to demonstrate that, under the influence of variations in the proportions of products of metabolism and electrolytes at given points in the system, rhythmical variations in permeability may be produced in the protoplasmic film permitting of the intake of food stuffs and output of waste products, and functioning in a manner somewhat analogous to the valve system of an engine or machine. If we consider the analogy of such a valve system, since the efficiency of a mechanical system may be entirely destroyed by too greatly increasing or too greatly diminishing the size and speed of action of the valves, it is not difficult to understand how substances like $CaCl_2$, by diminishing the permeability, and substances like $NaCl$, by increasing the permeability of the protoplasmic membrane beyond those comparatively narrow limits within which vital functions may be performed, would ultimately cause a sufficient disturbance of colloidal equilibrium to bring about what we designate as the death of the cell. The variations in electrical potential exhibited between the inside and outside of the cell, and the electrical effects exerted by given salts correspond with this theory. These experiments with antagonistic electrolytes afford substantial support to the theory, first advanced by A. B. Macallum, that the similarity in the proportions of certain electrolytes in sea-water, the blood of mammals, etc., is attributable to the fact that living protoplasm

has inherited from its original protoplasmic ancestor an adjustment of colloidal equilibrium to those electrolytes which were present in sea-water at the time that protoplasmic material first came into being. In other words we may say that electrolytes play, and always have played, an extremely important rôle in conditioning the form and structure, and maintaining the equilibrium of the complex colloidal system which we designate as living protoplasm. For further details regarding these and other experiments, and the methods employed, reference must be made to a paper in the May number of the *Journal of Physical Chemistry* and to other papers which will shortly appear in the *Journal of Physical Chemistry*, the *American Journal of Physiology*, etc.

In conclusion the writer wishes to acknowledge his great indebtedness to Mr. F. West for his cooperation in the conduct of the experiments recorded in this communication.

G. H. A. CLOWES

THE ORGANIZATION OF THE PACIFIC PHYSICAL SOCIETY

THE first meeting of the Pacific Physical Society was called to order by Professor Fernando Sanford at 3 o'clock on March 4 in Room 370, Stanford University Quadrangle. Forty members of the various departments of physics, physical chemistry and chemistry of the Pacific coast universities were present.

Professor E. P. Lewis, of the University of California, was called to the chair, and the following program was presented:

The Electromotive Force produced by the Acceleration of Metals: RICHARD C. TOLMAN and T. DALE STEWART.

This paper described some experiments on the mass or inertia of the carriers of electricity in metals. Similar effects have been looked for by previous investigators, Maxwell,[1] Lodge[2] and Nichols,[3] without apparatus sensitive enough for the purpose.

[1] Maxwell, "Treatise on Electricity and Magnetism," 3d ed. (1892), Vol. II., pp. 211 *et seq.*

[2] Lodge, "Modern Views of Electricity," 3d ed. (1907), p. 89.

[3] Nichols, *Physik. Z.*, 7, p. 640 (1906).

A coil of wire was rotated about its axis and suddenly brought to rest. The two ends of the rotating coil were connected through an external circuit with a highly sensitive ballistic galvanometer and the deflection of the galvanometer noted when the coil was stopped, the pulse of electricity thus measured being produced by the tendency of the electrons in the wire to continue in motion after the rest of the coil was at rest. A number of serious accidental effects had to be eliminated.

From the results of the measurements it was possible to calculate the effective mass of the electron in copper, silver and aluminum, the values obtained being not far different from that of the mass of the electron in free space.

The authors believe that their results are in accord with the "free electron" theory of metallic conduction and present serious obstacles to Sir J. J. Thomson's[4] recent theory of the conducting process in metals.

Contact Electromotive Force of Amalgamated Metals: F. J. ROGERS.

Electromotive Force of Metallic Sulphide Electrodes: S. W. YOUNG and W. E. BURKE.

Change of Potential of the Same Metal in Different Electrolytic Solutions: PHILO F. HAMMOND.

Voltaic cells were formed by using platinum electrodes for both the cathode and the anode, but with different salt solutions surrounding each electrode, the two solutions being connected by a capillary tube or a gelatine partition. One tenth normal solutions were used in every case. Each

Metallic Ion in Nitrate Solution Used	When Measured Against Silver Nitrate	When Measured Against Potassium Nitrate	Single Electrode Potentials with Silver Reduced to Zero
Ag	0	0.658	0
Fe[5]	0.114	0.544	?
Cu	0.392	0.266	0.44
H	0.509	0.149	0.77
Pb	0.537	0.121	0.92
Ni	0.560	0.098	0.985
Co	0.565	0.093	0.99
Fe[6]	?	?	1.10
Cd	0.594	0.064	1.19
Zn	0.600	0.058	1.54
Mg	0.623	0.035	2.54
Ca	0.632	0.026	2.94
Ba	0.647	0.010	3.44
Na	0.653	0.005	3.90
K	0.658	0	3.94

[4] Sir J. J. Thomson, *Phil. Mag.*, 30, 192 (1915); see also Richardson, *Ibid.*, 30, 295 (1915).

[5] Ferric nitrate.

[6] Ferrous nitrate.